Monitoring of Vibrations from Gaia-Wind Turbines

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Introduction

Situated at Eskdalemuir, near Langholm, in the Scottish Borders, the Comprehensive Test Ban Treaty International Monitoring System monitors for all types of nuclear explosions; the site constitutes the UK's seismological contribution to the Treaty.


Gaia-Wind 133 Lattice tower

Previous Keele studies concluded that micro-seismic noise is propagated through the ground from large wind turbines, as the rotation of the blades excite resonant modes of the tower. These vibrations have the potential to adversely impact the detection capabilities of the Eskdalemuir array and limits were set on the permissible aggregate vibrations. As this limit is now approaching, the MOD has placed a ban on all new wind turbines within a 50km radius of the site, seriously impacting the deployment of both large and small turbines with over 2.5GW of new capacity on hold.

At the time, the terms of reference of the previous study did not consider small or medium wind turbines. As government policy actively encourages micro-generation schemes, a research project has been established at Keele University to investigate what steps can be taken to permit small-scale wind development, whilst maintaining the detection capabilities at Eskdalemuir. The project involves the modelling and monitoring of vibrations from a range of small wind turbines. This enables us to establish whether the same algorithms for calculating the micro-seismic noise level applicable to the large turbines can be appropriately applied to small systems. This is essential for future small and medium wind turbine developments in the area.

Two wind turbines are monitored here, both manufactured by Gaia-Wind. They both have the same nacelle (top section) and blades, but differ in the tower; one is tubular and the other a lattice.

Monitoring Methodology

Seismic monitoring is used to determine the resonant frequencies of the tower. Vibrations are measured for several days so that data for various wind speeds and directions is obtained.

Uniaxial accelerometers are attached to the structure and in the ground at various distances from the turbine. Three component accelerometers and seismometers placed further away allow attenuation of the vibrations through the ground to be calculated. An anemometer is used to monitor the wind speed and direction.

The accelerometers are connected to a digitiser which is controlled by a laptop that records the data.

The seismometer is self contained (except for battery and GPS) and records the data to built in flash memory.


The anemometer mounted on a 6m mast.

Spectral analysis is performed on the accelerometer and seismometer data to determine the frequencies of vibrations produced by the turbine. This is compared with the wind speed and direction data to find correlations.

Far left - Unaxial accelerometers attached to the lattice tower
Left - 3-component accelerometer
Right - 3-component seismometer
Top left - The digitiser and laptop recording system


Dun Law wind farm in the Southern Uplands of Scotland

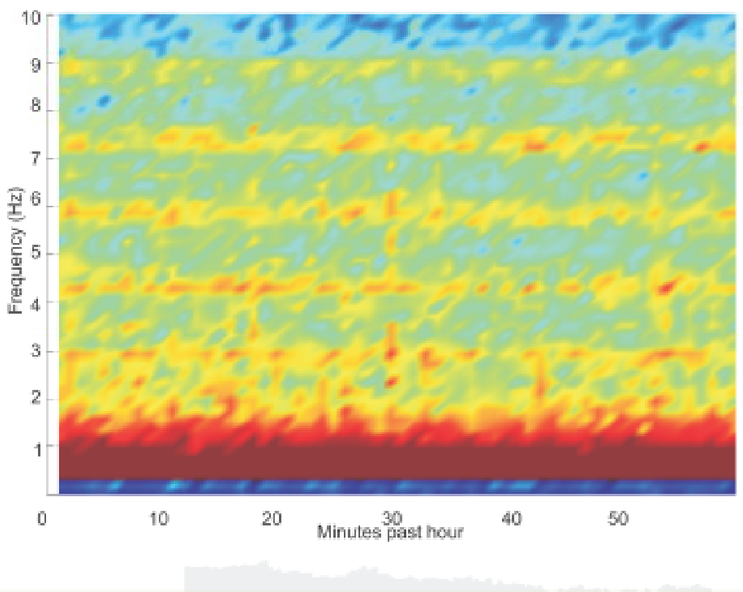
Previous Work

Previous work carried out by our group in the Southern Uplands of Scotland has shown that large turbines generate vibrations in the 4 to 6 Hz frequency range. This range of frequencies is the most critical for the verification of compliance with Comprehensive Test Ban Treaty.

The work is used by the MoD to set a permitted limit on the amount of vibration from wind turbines in the vicinity of Eskdalemuir. This resulted in a total prohibition within 17.5km of the site and a "Noise Budget" within 50km (See map above).

The figure below is a spectrogram showing how the frequency of the vibration varies during one hour. Red is high and blue is low amplitude of the vibration.

The plot shows strong peaks in the energy at certain frequencies. These frequencies are related to the structural modes of the tower and the rotation of the blades. There is a strong peak between 4 and 6 Hz. In this example the data was recorded about 2km from the windfarm, although the vibrations were detected over 10km away.

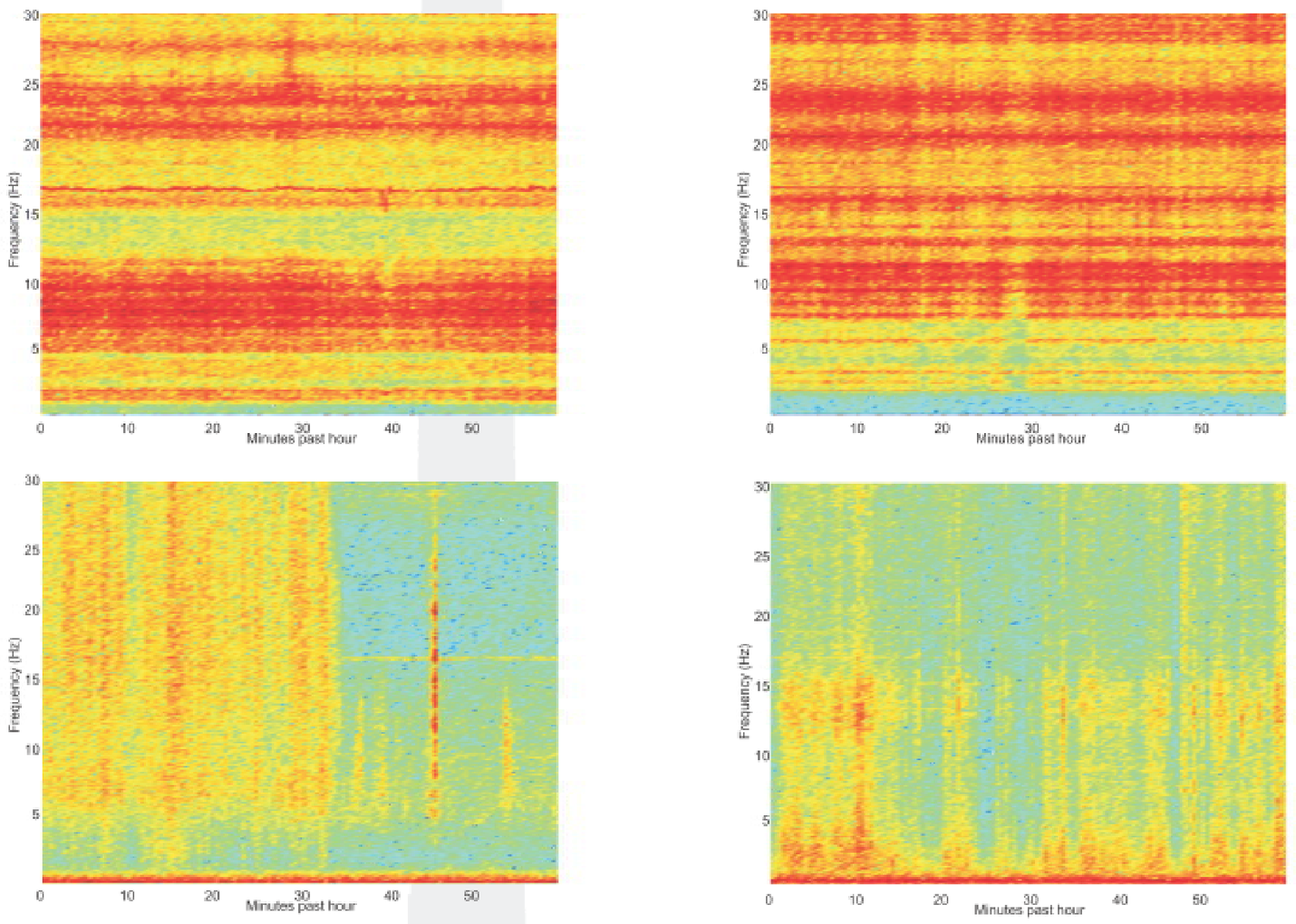


Results

The plots below show data collected while monitoring Gaia Wind turbines, the left hand plots are for a tubular tower and the right hand for a lattice tower.

The turbine was operational in both cases and the wind speed averaged approximately 4ms^{-1} for the tubular tower and 8ms^{-1} for the lattice.

The upper plots show spectrograms from an accelerometer attached to the tower, the lower plots are from a seismometer about 200m from the turbine.



Summary

From the spectrogram plots it can be seen that the peaks in the accelerometer data are no longer visible at a distance from the turbine. This suggests that the structural vibrations of the turbines are not well coupled with the ground and that they do not propagate far through the ground.

Following this study further discussions with the MoD are now required regarding the status of small wind turbines in the Eskdalemuir area.

Hopefully these discussions would allow landowners and farmers in Southern Scotland to take advantage of small scale wind developments to produce sustainable energy at low cost.

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